

On the spin modulated circular polarization from the intermediate polars NY Lup and IGRJ1509-6649.

Stephen B. Potter^{1*}, Encarni Romero-Colmenero^{1,2}, Marissa Kotze^{1,6},
Ewald Zietsman^{1,3}, O. W. Butters^{4,7}, Nikki Pekeur^{1,5} & David A. H. Buckley^{1,2}

¹*South African Astronomical Observatory, PO Box 9, Observatory 7935, Cape Town, South Africa*

²*Southern African Large Telescope Foundation, PO Box 9, 7935 Observatory, Cape Town, South Africa*

³*Department of Mathematical Sciences, The University of South Africa, PO Box 392, UNISA, 0003, South Africa*

⁴*Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH, UK*

⁵*Centre for Space Research, North-West University, Potchefstroom Campus, Private Bag X6001, Potchefstroom 2520, South Africa*

⁶*Astronomy Department, Astrophysics, Cosmology and Gravity Centre (ACGC), University of Cape Town, Rondebosch 7701, South Africa*

⁷*Department of Physics and Astronomy, The Open University, Walton Hall, Milton Keynes, MK7 6AA*

ABSTRACT

We report on high time resolution, high signal/noise, photo-polarimetry of the intermediate polars NY Lup and IGRJ1509-6649. Our observations confirm the detection and colour dependence of circular polarization from NY Lup and additionally show a clear white dwarf, spin modulated signal. From our new high signal/noise photometry we have unambiguously detected wavelength dependent spin and beat periods and harmonics thereof. IGRJ1509-6649 is discovered to also have a particularly strong spin modulated circularly polarized signal. It appears double peaked through the I filter and single peaked through the B filter, consistent with cyclotron emission from a white dwarf with a relatively strong magnetic field.

We discuss the implied accretion geometries in these two systems and any bearing this may have on the possible relationship with the connection between polars and soft X-ray-emitting IPs. The relatively strong magnetic fields is also suggestive of them being polar progenitors.

Key words: accretion, accretion discs – methods: analytical – techniques: polarimetric – binaries: close – novae, cataclysmic variables – X-rays: stars.

1 INTRODUCTION

The standard picture of a cataclysmic variable (CV) is a binary system consisting of a Roche lobe filling red dwarf (known as the secondary or the donor star) and an accreting white dwarf (the primary). CVs have orbital periods of typically a few hours, and mass transfer is caused by angular momentum loss - see e.g. Warner (1995) for a review of cataclysmic variables. Approximately 20% of the known CVs are magnetic cataclysmic variables (mCVs), where the white dwarf has a strong magnetic field (see the catalogue of Ritter & Kolb 2003). These are further sub-divided into two subtypes, namely intermediate polars (IPs) and polars, depending on the strength of the magnetic field of the white dwarf (see e.g. Vrielmann & Cropper 2004 and Patterson 1994 for a review of these objects).

In IPs it is thought that the white dwarfs magnetic field

truncates the inner edge of the accretion disc. Accretion is then magnetically channeled, via accretion curtains, onto the rapidly rotating white dwarf. The stronger magnetic field of polars prevents the formation of a disc entirely and instead accretion occurs onto small localized region(s), via magnetically confined streams, near the magnetic pole(s) of the orbitally synchronised white dwarf. Chanmugam & Ray (1984) suggested that IPs evolve into polars but, as yet, it is not fully supported through observations. In particular there is a lack of polarized emission from IPs compared to polars (in quantity and magnitude). It may be possible that the polarized light from IPs is somehow quenched either by absorption or by emission from the accretion disc and/or the accretion curtain for example. On the other hand, as the white dwarfs in IPs rotate asynchronously, it may suggest that their magnetic moments are less than those in polars. Wickramasinghe, Wu & Ferrario (1991) performed the first detailed calculation of polarized emission from IPs which showed that the magnetic fields in IPs is less than 5MG.

* sbp@sao.ac.za

They also argue that IPs above the period gap do not evolve into polars below the period gap but instead the white dwarf remains asynchronous with the resulting clumpy accretion giving rise to emission mainly in the EUV. Additional theoretical studies (Zhang, Wickramasinghe & Ferrario 2009) also suggest that if the relatively high mass transfer rate in IPs, compared to polars, is greater than a critical value, then the field tends to be advected toward the stellar equator where it is then buried.

IPs have also been thought of as hard X-ray sources and polars as softer X-ray sources. However many IPs in recent X-ray surveys are shown to have a distinct blackbody component in softer X-rays (e.g. Mason et al. 1992; Haberl et al. 1994; de Martino et al. 2004). Haberl & Motch (1995) suggested that there are two distinct classes of IP, with the soft systems being evolutionary progenitors of polars. Evans & Hellier (2007) made a systematic analysis of the *XMM-Newton* X-ray spectra of IPs and find that most actually show a soft blackbody component. They put forward that whether an IP shows a blackbody component depends primarily on geometrical factors. I.e. in systems that do not show any blackbody emission is as a result of their heated accretion pole caps being largely hidden by the accretion curtain. The sample analysed by Evans & Hellier additionally showed that the soft IPs also tended to be polarized emitters in agreement with the geometrical interpretation.

Therefore good quality multi-filtered polarimetry can, to a first order approximation, give the magnetic field strength of the white dwarf and also give insights into the accretion geometry thereby improving our understanding of these systems. Only eight IPs have been found to emit polarized light and therefore these new additions represent a significant increase to the sample. Those IPs where circular polarization has been found so far are: BG CMi (Penning, Schmidt & Liebert 1986; West, Berriman & Schmidt 1987), PQ Gem (RE 0751+14) (Rosen, Mittaz & Hakala 1993; Pirola, Hakala & Coyne 1993; Potter et al. 1997), V2400 Oph (RX J1712.62414) (Buckley et al. 1997), V405 Aur (RX J0558.0+5353) (Shakhovskoj & Kolesnikov 1997), V2306 Cyg (1WGA J1958.2+3232) (Uslenghi et al. 2001; Norton et al. 2002), 1RXS J173021.5-055933 (Butters et al. 2009), RX J2133.7+5107 (Katajainen et al. 2007) and NY Lup (Katajainen et al. 2010).

1.1 Previous observations of NY Lup

Haberl, Motch & Zickgraf (2002) identified the *ROSAT* source 1RXSJ154814.5-452845 (NY Lup) as an IP using optical and X-ray observations. They detected the 693 s spin period for the white dwarf in both the optical and X-ray light curves. NY Lup possesses a highly absorbed hot black-body soft X-ray component. Furthermore they showed that the optical spectrum is peculiar in that it shows broad absorption features underneath Balmer emission lines. de Martino et al. (2006) obtained the first detailed time resolved optical spectroscopy from which they determined the orbital period to be 9.87 ± 0.03 hours, the spectral type of the secondary star to be $K2 \pm 2$ V, a mass ratio of $q = 0.65 \pm 0.12$, $M_{WD} \geq 0.5 M_{\odot}$, $M_{sec} = 0.4 - 0.79 M_{\odot}$, a distance of 540-840 pc and a binary inclination $25^{\circ} < i \leq 58^{\circ}$. de Martino et al. (2006) point out that at the distance of NY Lup implies that the Balmer absorptions are not due to the white

dwarf photosphere. Instead they suggest an origin in the accretion flow close to the white dwarf surface. They suggest that polarimetric observations are required to confirm that NY Lup is a low magnetic field white dwarf. Confirmation came with Katajainen et al. (2010) who discovered circular polarization at a level of $\sim -1.5\%$ and $<0.1\%$ through the I and B filters respectively from observations made on the *VLT*. However, the signal/noise was insufficient to detect convincingly a modulation on the spin period.

1.2 Previous observations IGRJ1509-6649

IGRJ1509-6649 was discovered in the *INTEGRAL*/IBIS survey in the 17-60 keV energy range (Revnivtsev et al. 2008) and in the 20-100 keV energy range (Barlow et al. 2006). Bremsstrahlung and power law fits gave $kT = 13.8 \pm 5.1$ keV and $\Gamma = 3.6 \pm 0.8$ respectively with a 20-100 keV flux of 1.38×10^{-11} erg s $^{-1}$ cm $^{-2}$. Followup spectroscopy identified it as a probable intermediate polar (Masetti et al. 2006). Pretorius (2009) published more detailed followup spectroscopic and photometric observations. The spectroscopy showed a clear radial velocity signal at 5.89 ± 0.01 h which was identified as the orbital period. In addition a strong photometric modulation at 809.42 ± 0.02 s was discovered which was taken to be the spin period of the magnetic white dwarf. Butters, Norton, Mukai and Barlow (2009) confirmed the IP classification with *RXTE* observations. The X-ray spin pulse profile is complex with a modulation depth that decreases with increasing X-ray energy. Their Bremsstrahlung spectral fit agrees well with (Barlow et al. 2006) with a column density that suggests absorption within the accretion flow. They did not find any evidence for an additional modulation at the beat period and the length of their data set probably precluded any detection of the orbital period.

2 OBSERVATIONS AND DATA REDUCTION

Table 1 shows a log of all the observations of NY Lup and IGRJ1509-6649. All observations were made with the HIPPO (HI-speed Photo-Polarimeter: Potter et al. 2010) on the 1.9m telescope of the South African Astronomical Observatory. The HIPPO was operated in its simultaneous linear and circular polarimetry and photometry mode (All-Stokes). Clear filtered observations (3500-9000Å) were defined by the response of the two RCA31034A GaAs photomultiplier tubes, whilst for others either a B or I filter was used.

Several polarized and non-polarized standard stars (Hsu & Breger 1982 and Bastien et al. 1988) were observed in order to calculate the position angle offsets, instrumental polarization and efficiency factors. Photometric calibrations made use of standard stars chosen from Landolt (1992). Background sky polarization measurements were also taken at frequent intervals during the observations.

Data reduction then proceeded as outlined in Potter et al. (2010). Figs. 1 and 2 show a sample of the reduced and binned observations for NY Lup and IGRJ1509-6649 respectively. A slightly different data reduction method was applied in order to produce the spin-phase-fold-binned polarimetry presented in Figs. 4 and 6. This took advantage of the high speed capabilities of the HIPPO. Specifically each

Table 1. Table of observations. All observations were obtained on the 1.9m telescope using the HIPPO (HI-speed Photo-Polarimeter) of the South African Astronomical Observatory.

Date	Target	Filter	Total time(hours)	length (orbits)	Weather conditions	Brightness
20/21 May 2009	NY Lup	Clear	~2.5	~ 0.4	poor	-
21/22 May 2009	IGRJ1509-6649	Clear	~6	~ 1.0	good	-
22/23 May 2009	IGRJ1509-6649	I	~6	~ 1.0	good	Imag = 14.5-15.3,
25/26 May 2009	NY Lup	Clear	~8	~ 0.8	good	-
26/27 May 2009	NY Lup	B,I	~8	~ 0.8	good	I,Bmag = 13.6-14,14.6-15
24/25 July 2009	IGRJ1509-6649	B,I	~5	~ 0.85	good	I,Bmag = 14.1-15,15.2-15.6

of the raw, one millisecond integrations were first phased on the respective spin periods of the target. Then, for a specified phase bin size, the data was binned according to the appropriate position of the polarimetry optics (namely the wave-plate angles). Next, the instrumental polarization, efficiency factors and sky background were applied to the binned data. Finally the polarization was calculated for each of the phase bins. This has the advantage of significantly improving the S/N of the data by maximizing the amount of signal in each phase and wave-plate bin before calculating the polarization.

3 RESULTS

3.1 NY Lup

Fig. 1 shows a sample of our observations of NY Lup. Specifically the simultaneous I and B filtered photo-polarimetric observations taken on the nights of 26/27 May 2009. The I and B magnitudes (13.8-14. and 14.7-15.) are broadly consistent with the observed V magnitudes (14.5-14.7) reported by Haberl et al. (2002). The 693s white dwarf spin modulation can clearly be picked out in the I filter photometry. The I filtered circular polarimetry shows variability mostly confined between -1 and -2 percent with some excursions to 0 and -3 percent. The B filtered circular polarimetry also shows variability but appears to be more centered on 0 percent. It is difficult to visually pick out any periodic modulation in any of the polarimetry given the signal/noise.

We subjected all the photometry and polarimetry to fourier analysis. In Fig. 3 we present the amplitude spectra of NY Lup. The left and right plots display the photometry and corresponding circular polarimetry respectively. The top plots were constructed from the 25 May 2009 observations where both HIPPO channels used the clear filter and were consequently co-added before fourier analysis. The lower four plots were constructed from the 26 May 2009 observations where B and I filters were used simultaneously, one in each of the two channels.

The amplitude spectra of the clear filtered photometry is dominated by a singular peak centered midway between the known spin and beat periods (shown as vertical dashed lines) of NY Lup. Ignoring the lowest frequencies, the I filtered amplitude spectra displays its largest peak centered on the spin period. The second largest peak is centered on the beat period. The B filtered amplitude spectra however

does not show any power at the spin period but is instead dominated by a peak at the beat period.

The corresponding clear filtered circular polarimetry has a significant peak coincident with the spin period thus formalizing the discovery of spin modulated circular polarization in NY Lup. A similarly located peak is present in the I filtered circular polarimetry, although to a lesser extent. The B filtered circularly polarized amplitude spectra shows no signal above the noise at the spin period.

The spin modulation is confirmed in the upper plots of Fig. 4 where we have spin-phase-fold-binned the clear filtered photometry and polarimetry on the spin period of NY Lup (we have used the NY Lup spin ephemeris of de Martino et al. 2006). The photometry was normalised by a linear fit before spin-phase-fold-binning and the error bars represent the standard deviation of the data in each bin. The photometry and circular polarimetry show sinusoidal variations roughly in phase with each other. The circular polarization modulation remains negative throughout the whole spin cycle between a level of -0.6 and -1.0 percent. Similarly the I filtered photometry is sinusoidally modulated and in phase with the clear filtered photometry. The I filtered circular polarimetry is also sinusoidally modulated between approximately -2 and -2.5 percent, however it is anti-phased with respect to the photometry and the clear filtered circular polarimetry. The B filtered photometry shows no modulation on the spin period, confirming the results of the fourier analysis. However the B filtered circular polarimetry appears to show a slight sinusoidal modulation (between approximately 0 and -0.4 percent) which is not too unexpected given the small peak in the amplitude spectra. It appears to be in phase with the clear filtered observations.

Linear polarization was detected at a level of ~1.5, ~1.0, ~2.0 in the clear, I and B filters respectively. No significant periods were detected in the fourier analysis and no variability is seen after spin-phase-fold-binning the data (plots not shown).

3.2 IGRJ15094-6649

Fig. 2 shows a sample of our data sets on our observations of IGRJ15094-6649. Specifically the simultaneous I and B filtered photo-polarimetric observations taken on the nights of 24/25 July 2009. The I and B magnitudes (15.-14. and 15.7-15.) are broadly consistent with the observed V magnitudes (15.-14.5) reported by Pretorius (2009). The 809s white dwarf spin modulation can clearly be picked out in

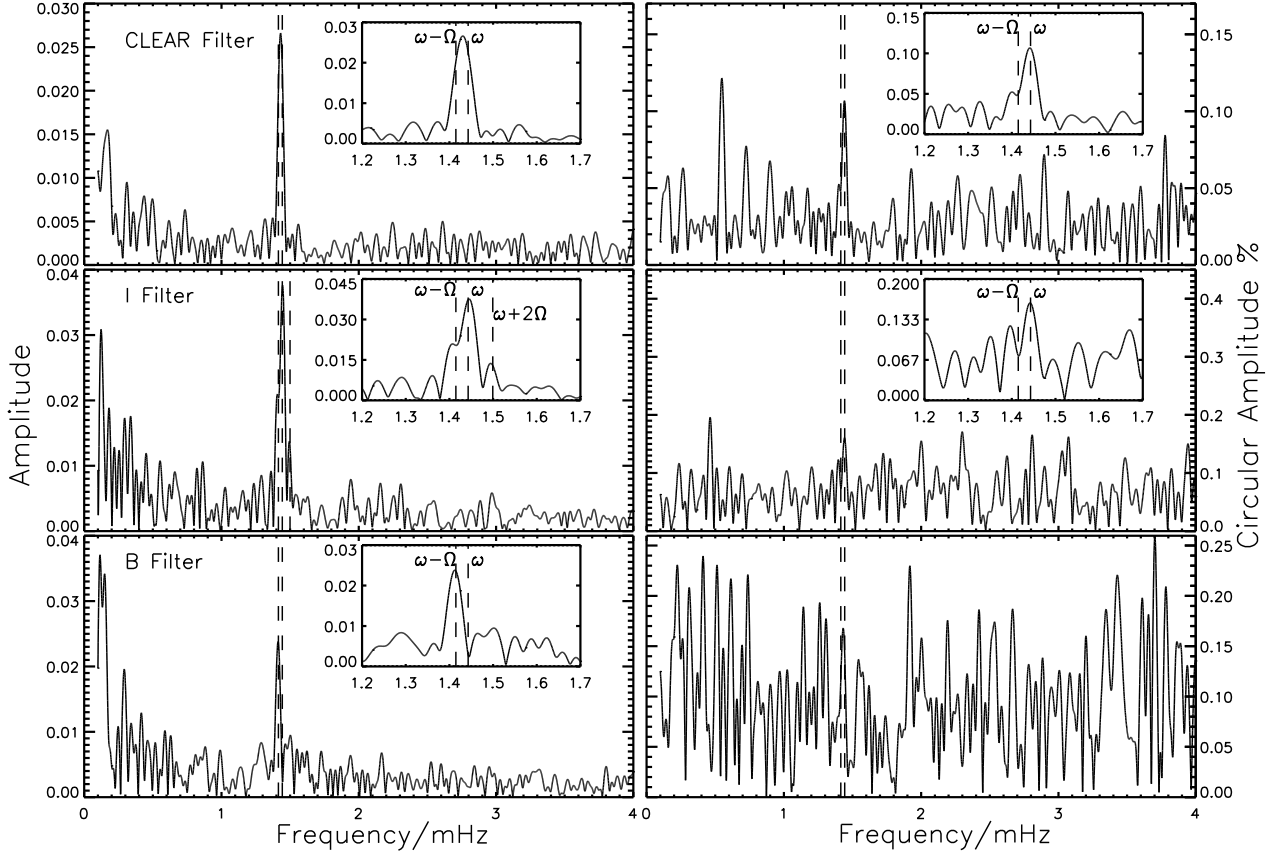


Figure 3. Left and right-hand panels respectively: The photometry and circular polarimetry amplitude spectra of NY Lup. The photometry was normalised by a linear fit before fourier analysis.

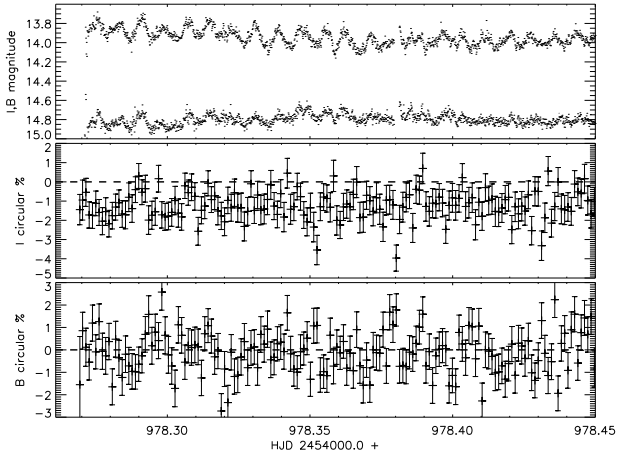


Figure 1. A sample of the simultaneous I and B filtered photometry (binned to 10s) and circular polarimetry (binned to 100s) of NY Lup taken during the nights of the 26/27 May 2009. The I and B photometry are the top and bottom light curves respectively.

the I and B filtered photometry. The I and B filtered circular polarimetry show variability mostly confined between 0 and 2 percent with some excursions to 3 percent. It is diffi-

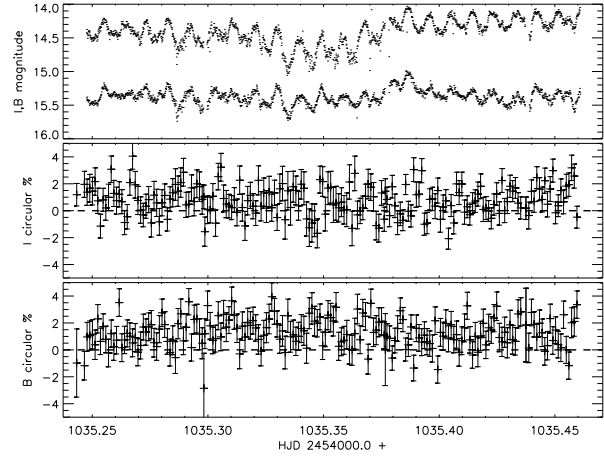


Figure 2. A sample of the simultaneous I and B filtered photometry (binned to 10s) and circular polarimetry (binned to 100s) of IGRJ1509-6649 taken during the nights of the 24/25 July 2009. The I and B photometry are the top and bottom light curves respectively.

cult to visually pick out any periodic modulation in any of the polarimetry given the signal/noise.

We subjected all the photometry and polarimetry to

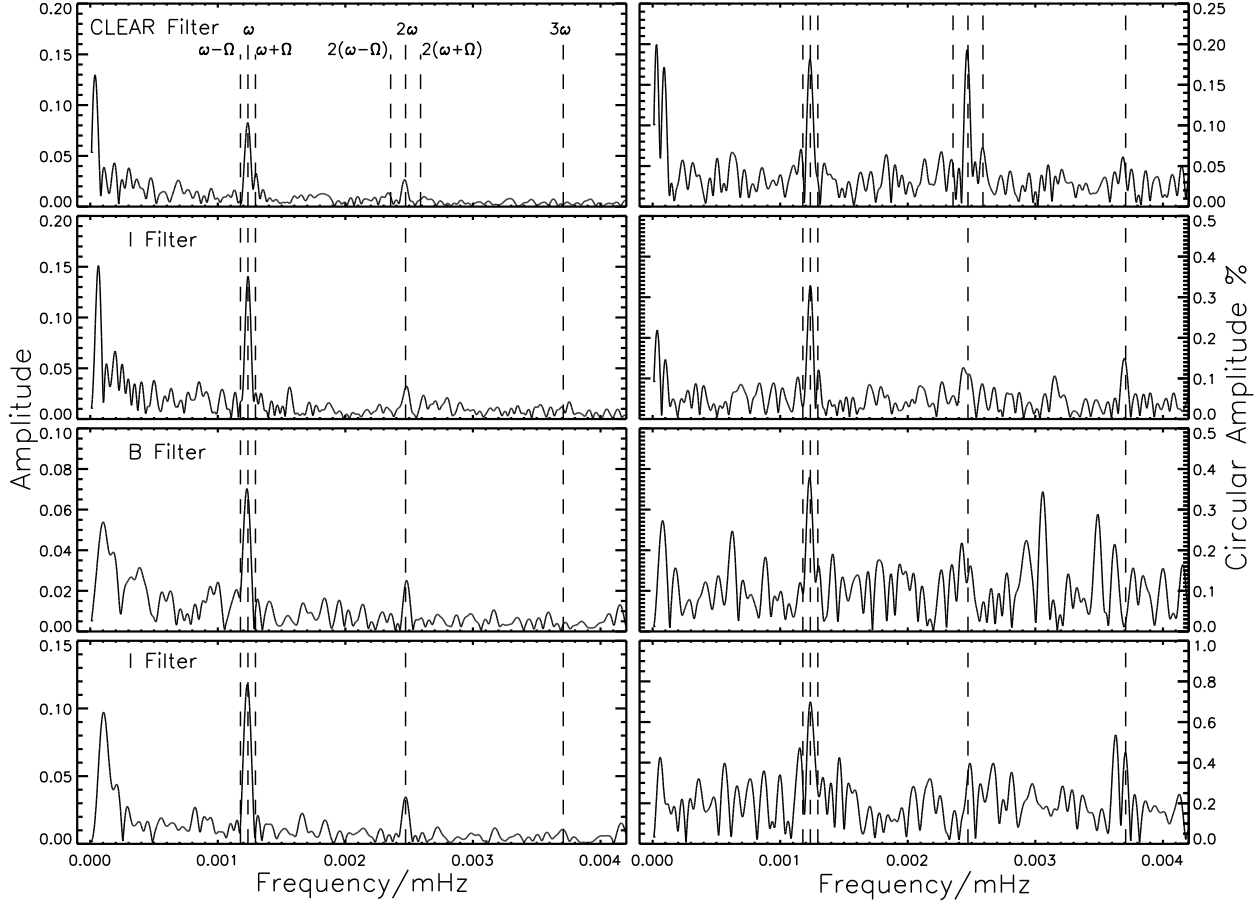


Figure 5. Left and right-hand panels respectively: The photometry and circular polarimetry amplitude spectra of IGRJ1509-6649. The photometry was normalised by a linear fit before fourier analysis. Beat period derived from 1 day alias of Pretorius (2009) orbital period.

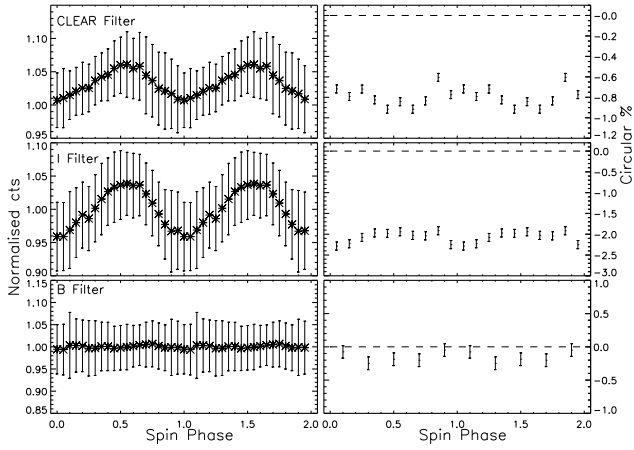


Figure 4. Left and right-hand panels respectively: The spin-phase-folded photometry and circular polarimetry of NY Lup. The photometry was normalised by a linear fit before phase-folding. The I and B filters are simultaneous.

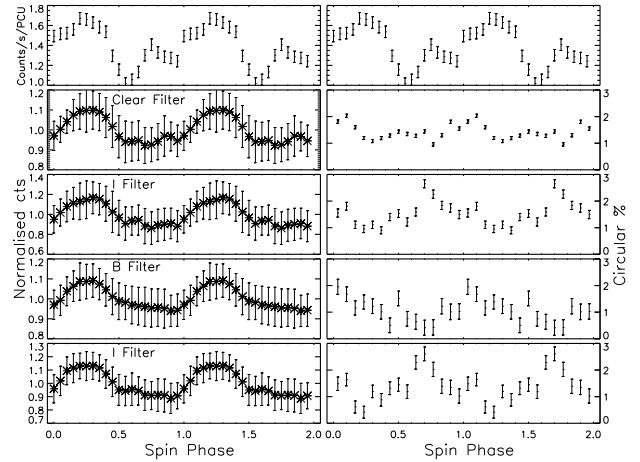


Figure 6. Left and right-hand top panels: RXTE spin-phase-binned observations plotted twice. Remaining left and right-hand panels respectively: the spin-phase-binned photometry and circular polarimetry of IGRJ1509-6649. The photometry was normalised by a low order polynomial fit before phase-binning.

fourier analysis. In Fig. 5 we present the amplitude spectra of IGRJ1509-6649. The left and right plots display the photometry and corresponding circular polarimetry respectively. The top plots were constructed from the 21 May 2009

observations where both HIPPO channels used the clear filter and were consequently co-added before fourier analysis. Similarly the next row (of 2 plots) show the results from

co-adding the I filtered observations of 22 May 2009. The lower four plots were constructed from the 24 July 2009 observations (1 month later) where B and I filters were used simultaneously, one in each of the two channels.

All of the photometric amplitude spectra are dominated by a peak centered on the known spin period (shown as vertical dashed lines) of IGRJ15094-6649. A significant peak is also visible at twice the spin period in all filters. Our data sets are not sufficiently long to detect the orbital period and the Fourier analysis does not show anything significant at the expected beat period. However, the next significant peak in the clear filter photometry has a period of ~ 773 s. If this were the beat period ($\omega + \Omega$) then it would imply an orbital period of 4.73 hours which would correspond to a one day alias of the orbital period from Pretorius (2009). Her figure 2 does indeed show 1 day aliasing. We also calculated the amplitude spectra of the combined May and July I filtered photometry (not shown). After pre-whitening the photometry with the spin period, the next most significant peak (after the spin harmonics) has a period of 848s. This would be consistent with a $(\omega - \Omega)$ beat period again assuming the orbital period is 4.73 hours. However we note that this peak is comparable in amplitude to the low frequency noise and therefore further observations are required to unambiguously identify the orbital period.

The corresponding circular polarimetry (all filters) have a significant peak coincident with the spin period thus formalizing the discovery of spin modulated circular polarization in IGRJ15094-6649. An equally significant peak is located at twice the spin period in the clear filtered circular polarimetry which may be present in the 2 sets of I filtered circular polarimetry.

Linear polarization is seen at a level of ~ 0.5 percent in all filters (not shown) however the signal/noise is not sufficient to assign a firm detection. In addition no significant periods were detected in the Fourier analysis.

The spin modulation is confirmed in the left plots of Fig. 6 where we have spin-phase-fold-binned the photometry on the spin period of IGRJ15094-6649. The two upper (left and right) plots show the *RXTE* observations from Butters et al (2009) for comparison (see below). The photometry was normalised by a linear fit before spin-phase-fold-binning and the error bars represent the standard deviation of the data in each bin. We originally spin-phase-fold-binned our observations on the spin period of Pretorius (2009), however the May and July observations showed a phase shift (~ 0.15) with respect to each which we attributed to an accumulation of the error in the estimate of the white dwarf spin period. We therefore spin-phase-fold-binned our observations on the following Barycentric corrected spin ephemeris to bring the data in line with each other:

$$T(BJD(tdb)) = 2454973.290 + 0.00936848(4)E$$

BJD is the Barycentric Julian Date in the barycentric dynamic time system (tdb).

The photometry shows approximately sinusoidal variations in all filters. We also extracted and re-reduced the *RXTE* observations originally published in Butters et al. (2009) and spin-phase-fold-binned on our new spin ephemeris. Although the *RXTE* observations show a more

complicated variation, the general morphology appears to be in phase with our new photometry.

The circularly polarized spin-phase-fold-binned data is shown in the right plots of Fig. 6. The clear circular polarimetry varies between ~ 1.0 and ~ 2.0 percent, rising unevenly from its minimum value at phase ~ 0.3 to a maximum at phase ~ 1.1 . The unevenness explains the harmonics seen in the amplitude spectra of Fig. 5. The third and fifth plots show the I filtered circular polarimetry separated by 2 months. They appear to be morphologically identical varying between ~ 1.0 and ~ 2.5 percent with minimum and maximum values at phases ~ 0.3 and ~ 0.7 respectively. The B filtered circular polarimetry (fourth plot) is simultaneous with the I filtered observations (fifth plot) and displays a saw tooth variation between values of ~ 0.5 percent, at phase ~ 0.7 , and ~ 2.0 percent at phase ~ 0.1 . The maximum and minimum between the I and B filtered circular polarimetry appear to be approximately anti-phased w.r.t. each other.

4 DISCUSSION AND SUMMARY

4.1 NY Lup

Our photometry confirms the 9.87 h orbital period through the detection of a strong optical beat period ($\omega - \Omega$) which particularly dominates in the B filter. It is also present in the I filter where the spin period is most dominant. A significant ($\omega + 2\Omega$) is also detected in the I and B filters. The spin period is not present in the B filter. The beat period was only weakly detected in the V filter by Haberl et al. (2002) after demodulation from the dominant spin frequency. Neither the spin nor the beat periods were detected in the spectroscopic continuum observations of de Martino et al. (2006).

Ferrario & Wickramasinghe (1999) have shown that, for single pole stream-fed accretion, significant power is expected in the optical at ($\omega - \Omega$). In contrast, for disc accretion, the dominant power in the continuum and line fluxes is always at the spin frequency ω . We have found significant power at both ($\omega - \Omega$) and ω . The single most important feature that allows a clear distinction to be made between disc-fed and stream-fed accretion is the amplitude of the radial velocity variations. These have been measured to be relatively low by de Martino et al. (2006) which suggests accretion is disc fed. Our observed beat period probably arises as a result of reprocessing of the primary radiation by other components of the system such as the accretion curtains, the secondary star or regions on the accretion disc including the hotspot.

We confirm the detection of circular polarization of Katajainen et al. (2010) from NY Lup and its B, I colour dependence, although our I filter observations are higher by $\sim 0.5\%$. Additionally our amplitude spectra show unambiguously that the circular polarization is modulated on the white dwarf spin period. The spin modulation was not detected by Katajainen et al. (2010) probably due to their lower signal/noise and/or poorer time resolved *VLT* observations. The B and I filter circular polarization are single humped, negative for the whole spin cycle, but anti-phased with respect to each other. Buckley et al. (1995) observed similar behaviour in the IP RXJ1712.6-2412. Maximum I circular polarization is centered on phase zero coincident with

the observed maximum red shift in the HeII emission line (de Martino et al 2006). This is consistent with the orientation of the magnetic field lines, in the cyclotron emission region, approaching close to parallel to the line of sight at this phase. This combined with the increase in polarization towards the red and the colour dependence of the phase for the circular polarization variation, can be interpreted as an accretion curtain geometry and a magnetic field $> 4\text{MG}$. However de Martino et al. (2006) came to the conclusion that its magnetic field strength is actually lower than 2 MG and Norton et al. (2004) gave estimates $\mu < 1.4 \times 10^{33} \text{Gcm}^3$ for $q = 0.5$ for the magnetic moment. Given this disparity it is not possible to estimate the evolutionary path of NY Lup. Nevertheless the fact that NY Lup is a “soft” IP and shows spin modulated polarization is consistent with the geometrical interpretation of IPs (Evans & Hellier 2007) in order to explain their X-ray spectral distributions.

We note that the true spectral dependence of the polarimetry is not yet fully understood because of the strong possibility that some of the polarized emission in NY Lup originates from halo Zeeman lines (de Martino 2006). It is thought that halo Zeeman lines are attributed to free-falling cool material in the vicinity of the shock. This has been observed in some polars (e.g. MR Ser: Schwöpe et al. 1993). Further understanding would require spin-phase resolved spectro-polarimetry and NY Lup would be a unique opportunity for such an investigation.

Variability in the linear polarization is not detected suggesting that the magnetic field lines, in the cyclotron emission region, never approach an orientation close to perpendicular to the line of sight. This is consistent with a relatively low inclination, single accreting pole system. The second accretion pole being out of sight.

4.2 IGRJ15094-6649

We have found that the IP IGRJ15094-6649 emits circularly polarized light. The polarization is between ~ 1.0 percent and ~ 2.5 percent in the I filter and ~ 1.0 percent and ~ 2.0 percent in the B filter.

With an orbital period > 3 hours and a $P_{\text{spin}}/P_{\text{orb}} = 0.048$ this puts it with the “regular” disc-fed IPs according to Norton, Wynn & Somerscales (2004) and Norton et al (2008) and hence it should share similar properties to the well studied polarized IPs, V2400 Oph (Buckley et al. 1995) and PQ Gem (Potter et al 1997). The wavelength and phasing dependence of the positive only circular polarimetry is almost identical to V2400 Oph, suggesting that it has a single pole-on geometry with an extended accretion curtain. However the spin period dominating amplitude spectra (also seen in the X-rays: Butters et al 2009) suggests that it is a disc fed system, more like PQ Gem. In fact, the X-ray/optical characteristics of IGRJ15094-6649 appear similar to the disc-fed and accretion curtain scenario of PQ Gem. In Fig. 6 we have plotted the *RXTE* and our new observations phased on our new spin ephemeris. As with PQ Gem, maximum X-ray and optical photometry occur when the accretion region is most face on to the viewer. Maximum circular polarimetry occurs just before or after, as one would expect from the angular dependence of cyclotron beaming.

The detection of significant levels of polarization in the B filter suggests that the white dwarf’s magnetic field

could be quite high, perhaps approaching those of polars ($> 10\text{MG}$), but detailed multi-filtered and/or spectropolarimetric observations are needed to measure more precisely the wavelength dependence of the circular polarimetry. IGRJ15094-6649 would then be similar to the high magnetic field IP V405 Aurigae (Piirola, Vornanen, Berdyugin and Coyne 2008) and could qualify as a likely candidate as a polar progenitor.

We have tentatively identified a beat period in our clear and I filtered photometry, which implies an orbital period of 4.73 hours. This corresponds to a one day alias of the orbital period measured from the radial velocities of the H_α line (Pretorius 2009). This beat period probably arises as a result of reprocessed radiation on the heated face of the secondary star or a hot spot on the accretion disc.

Further observations are required to fully understand this object, particularly orbit- and spin-resolved spectroscopy and spectro-polarimetry.

5 ACKNOWLEDGMENTS

This material is based upon work supported financially by the National Research Foundation. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and therefore the NRF does not accept any liability in regard thereto.

REFERENCES

- Barlow E. J., Knigge C., Bird A. J., Dean A. J., Clark D. J., Hill A. B., Molina M., Sguera V., 2006, MNRAS, 372, 224
- Bastien P., Drissen L., Menard F., Moffat A. F. J., Robert C. & St-Louis N., 1988, AJ, 95 900
- Buckley D. A. H., Haberl F., Motch C., Pollard K., Schwarzenberg-Czerny A. & Sekiguchi K. 1997, MNRAS, 287, 117
- Buckley D. A. H. et al. 1995, MNRAS, 275, 1028
- Butters O. W., Norton A. J., Mukai, K. & Barlow E. J., 2009, A&A, 498, L17
- Butters O. W., Katajainen S., Norton A. J., Lehto H. J. & Piirola V., 2009, A&A. 496, 891
- Chanmugam G. & Ray A. 1984, ApJ, 285, 252
- de Martino D., Matt G., Belloni T., Haberl F. & Mukai K., 2004, A&A, 415, 1009
- de Martino D., Bonnet-Bidaud J.-M., Mouchet M., Gnsicke B. T., Haberl F. & Motch C., 2006, A&A, 449, 1151
- Evans P. A. & Hellier C., 2007, ApJ, 663, 1277
- Ferrario L. & Wickramasinghe D. T., 1999, MNRAS, 309, 517
- Haberl F., Motch C. & Zickgraf F.-J., 2002, A&A, 387, 201
- Haberl F. & Motch C., 1995, A&A, 297, 37
- Hsu J. C., Breger M., 1982, ApJ, 262, 732
- Katajainen S., Butters O. W., Norton A. J., Lehto H. J. & Piirola V., 2007, A&A, 475, 1011
- Katajainen S., Butters O., Norton A. J., Lehto H. J., Piirola V. & Berdyugin A., 2010, ApJ, 724, 165
- Landolt, A. U., 1992, AJ, 104, 372
- Masetti N., et al. 2006, A&A, 459, 21
- Mason K. O., et al, 1992, MNRAS, 258, 749
- Norton A. J., Quaintrell H., Katajainen S., Lehto H. J., Mukai K. & Negueruela I., 2002, A&A, 384, 195
- Norton A. J., Wynn G. A. & Somerscales, 2004, ApJ, 614, 349
- Norton A. J., Butters O. W., Parker T. L. & Wynn G. A., 2008, ApJ, 672, 524

- Penning W. R., Schmidt G. D. & Liebert J., 1986, *ApJ*, 301, 881
- Pirola V., Hakala P. & Coyne G. V., 1993, *AnIPS*, 10, 305
- Pirola V., Vornanen T., Berdyugin A. & Coyne G. V., 2008, *ApJ*, 684, 558
- Potter S. B., Cropper M. S., Mason K. O., Hough J. H., Bailey J. A., 1997, *MNRAS*, 285, 82
- Potter S. B., et al. 2010, *MNRAS*, 402, 1161
- Pretorius M. L., 2009, *MNRAS*, 395, 386
- Revnivtsev M., Sazonov S., Krivonos R., Ritter H. & Sunyaev R., 2008, *A&A*, 489, 1121
- Rosen S. R., Mittaz J. P. D. & Hakala P. J., 1993, *MNRAS*, 264, 171
- Ritter H., Kolb U., 2003, *A&A*, 404, 301 (update RKcat7.9)
- Schwope A. D., Beuermann K., Jordan S. & Thomas, H.-C., 1993, *A&A*, 278, 487
- Shakhovskoj N. M. & Kolesnikov S. V., 1997, *IAUC*, 6760
- Uslenghi M., Tommasi L., Treves A., Pirola V. & Reig, P., 2001, *A&A*, 372, L1
- Vrielmann S. & Cropper M, Magnetic Cataclysmic Variables, IAU Colloquium 190, 2004, Proceedings of the Conference held 8-13 December, 2002 in Cape Town, South Africa. ASP Conference Proceedings, Vol. 315. San Francisco: Astronomical Society of the Pacific
- Warner B. 1995, *Cataclysmic Variable Stars*, Cambridge Astrophysics Series 28, Cambridge University Press
- West S. C., Berriman G. & Schmidt G. D., 1987, *ApJ*, 322, L35
- Wickramasinghe D. T., Wu K. & Ferrario L., 1991, *MNRAS*, 249, 460
- Zhang C. M. Wickramasinghe, D. T. & Ferrario L. 2009, *MNRAS*, 397, 2208